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YIELD REDUCTION from Controlled Flooding of CORN

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FLOODING at early stages of plant growth causes the greatest damage to corn, results of an Iowa State University study show.

In fact, the stage of growth of corn appears to be a bigger factor in crop damage than depth of flooding. Also influencing the amount of damage is the rate of fertilization and the length of the flooding period. The study also shows that large amounts of nitrogen may be lost from the soil during flooding, and that injury may be caused by factors other than excess water.

Each year floods cause millions of dollars worth of damage to crops and property. Yet, there is little information available on the specific effect flooding has on yields of corn. Specific information is vitally needed to estimate damages to crops in order to determine the value of planned flood control programs.

A U. S. Department of Agriculture evaluation of the Honey Creek watershed in Lucas County, Iowa, pointed out some of the shortcomings in methods now used to determine flooding damage to growing crops. Interviews with farm operators on the floodplain gave an indication of the reduced yields caused by flooding. But since damaging floods occurred more than once during the year, the USDA found current methods were poorly adapted to determining the separate influence of individual floods on yields.

To provide some of the needed answers, the agricultural engineering department at Iowa State University conducted a controlled flooding experiment to evaluate flood damages to corn inundated for variable periods of time at different stages of growth.

Method of Study

The studies were conducted during the summers of 1966, 1967, and 1968 on Colo soil, a floodplain soil with a permeable subsoil which drained well after water receded. In 1966, corn was flooded for 24, 48 and 72 hours with about 6 inches of water. The first flood water was applied when corn was about 6 inches high. Corn was also flooded when it was 30 inches high and at the silking stage. In 1967 and 1968, flooding periods were changed to 48, 72 and 96 hours.

Two different levels of nitrogen were used on the plots. High-nitrogen plots received 350 pounds of nitrogen per acre, and lower fertility plots received 50 pounds of nitrogen per acre. Water for flooding was obtained from an irrigation well. Plots were laid out and diked to retain the water.

Results

Results of the 1966 study show corn yields are affected most when flooding occurs at early stages of growth when corn plants are 6 inches tall or less. The high nitrogen plot yields were reduced 20 percent when flooded for 72 hours. A 35 percent yield reduction was observed on the low nitrogen plots when flooded 72 hours.

Some reduction in yield also occurred on both high and low fertility plots when flooded for 24 hours, and a greater reduction occurred when flooded for 48 hours (Table 1).

At later stages of growth, when plants were 30 inches tall, there was little effect from flooding except on the low-nitrogen plots. Yields were reduced about 15 percent on the low nitrogen plots when inundated for 72 hours at this stage of growth.

The duration of inundation had a greater effect on the low-nitrogen plots than the high nitrogen plots. The high rates of nitrogen seemed to give corn plants extra vigor and they were able to withstand long periods of flooding.

Again in 1967, results indicated corn yields are affected most when flooding occurs at the early stages of growth — 6 inches or less. The

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TABLE 1. Average yields of 1966 corn flooding experiment.

Corn height or stage at time of flooding (inches)	Length of flooding (hours)	Average yield (bu. per acre)	
		High nitrogen	Low nitrogen
6	72	102.6	81.2
6	48	105.5	93.0
6	24	107.8	98.4
30	72	127.6	101.4
30	48	116.3	99.7
30	24	126.4	103.7
Silking	72	137.5	118.5
Silking	48	127.1	122.8
Silking	24	139.7	117.5
	No flooding	125.9	120.9

affect of nitrogen was even more pronounced in the 1967 studies. At the 6-inch stage of growth, flooded low-nitrogen plots yielded 30 percent less than the unflooded plots after 96 hours. Under the same conditions, the high-nitrogen plots' yield was only 6 percent less than unflooded plots.

Low-nitrogen plot yields also were greatly reduced by flooding for longer periods at later stages of growth. When plants were 30 inches tall, low-nitrogen plot yields were reduced by 30 percent after 96 hours of flooding. The low nitrogen plot yields also were reduced by 16 percent when flooded for 96 hours at the silking stage (Table 2). Only a small reduction in yield was noted on the high-nitrogen plots after being flooded for 96 hours at either the silking or 30-inch stage of growth. All plots flooded for 96 hours yielded less than those inundated for 48 hours.

The results in 1968 (Table 3) substantiate that corn yields are affected most when flooding occurs at the early stages of growth—6 inches or less. Also nitrogen applications had a great effect on the corn yields of flooded corn in 1968.

The results indicate that heavier nitrogen applications are more effective in reducing yield losses if flooding occurs at the earlier stages of plant growth. Yield losses are still reduced, however, when heavier nitrogen applications have been made and flooding occurs at later stages of growth.

Dollar Costs

Analysis of the three-year test results show that 48 hours of flooding at the early stages of growth (plant height of 6 inches or less) result in a loss of about $32 per acre to corn on the low-nitrogen plots. With 72 hours of flooding at the early stage of growth, the loss was $39.50 per acre on low-nitrogen plots. Corn was estimated to be worth $1.15 per bushel in calculating losses, with the cost of harvesting and drying corn at 23 cents per bushel. The extra cost of nitrogen on the high-nitrogen plots was taken into consideration in calculating flood losses. Nitrogen losses resulting from flooding were not estimated in the flood damage costs.

In 1967, soil samples were taken to determine the amount of nitrogen lost during flooding. Samples were taken at 1-foot intervals to a depth of 4 feet. All the soil tests showed high amounts of nitrogen (200 to 300 pounds per acre) present in the first foot of the control plots where high rates of nitrogen were applied. After the different periods of flooding, the soil tests showed inorganic nitrogen varied from 15 to 35 pounds per acre in the top 12 inches of the soil profile. From 10 to 20 pounds per acre were found in the 12 to 48-inch depth on both the high and low-nitrogen flooded plots.

The low-nitrogen plots showed little variation in nitrogen losses for different lengths of flooding. On the high-nitrogen plots, however, the amount of nitrogen lost increased with the length of inundation (Figure 1).

The soil tests indicated 300 to 400 pounds of nitrogen per acre were lost by flooding in this study. This loss may not be as great under natural flooding because the water table rises and the degree of leach-

TABLE 2. Average yields of 1967 corn-flooding experiment.

Corn height or stage at time of flooding (inches)	Length of flooding (hours)	Average yield (bu. per acre)	
		High nitrogen	Low nitrogen
6	96	140.2	98.6
6	72	149.1	93.9
6	48	149.7	98.7
30	96	140.8	98.4
30	48	142.2	104.2
30	24	151.4	110.3
Silking	96	147.3	118.2
Silking	72	157.0	118.3
Silking	48	157.3	122.8
	No flooding	148.9	141.0

TABLE 3. Average yields of 1968 corn flooding experiment.

Corn height or stage at time of flooding (inches)	Length of flooding (hours)	Average yield (bu. per acre)	
		High nitrogen	Low nitrogen
6	96	144.2	92.4
6	72	143.6	83.9
6	48	151.4	93.3
30	96	148.7	102.2
30	72	145.8	105.4
30	48	148.6	122.4
Silking	96	161.4	125.9
Silking	72	155.8	125.0
Silking	48	154.9	120.1
	No flooding	135.2	130.6

ing may be less. Most of this nitrogen would be leached through the soil profile and carried away in the groundwater because the subsoil in the study had good internal drainage. Some of the nitrogen would be lost by volatilization through the reduction of nitrates to various forms of nitrogen gas.

The leaching and volatilization of nitrogen is a great economic loss because it often is the most expensive soil mineral of the major plant nutrients. These nitrogen losses are felt not only during the year of flooding, but over a period of succeeding years. Unless management practices and heavier fertilization are used to restore the nitrogen losses, future crops will show a nitrogen deficiency and lower yields will result.

Irrigation Effect

In some cases, the flooded plots outyielded the control plots. In the 1966 study, the unflooded plants probably were injured more by the dry midsummer weather than the plants on the late flooded plots were injured by excess water. Control plots were irrigated once in an attempt to maintain more normal growing conditions, but there was not sufficient moisture throughout the summer for the best crop growth. By the time the third flooding treatment was applied, there was a large deficiency of soil moisture. Therefore, the third flooding provided some irrigation benefit.

Natural Flooding

There appears to be a difference between natural flooding, and the "artificial" flooding used in these studies.

In the summer of 1966, 1967, and 1968 in Iowa, heavy June rains caused potholes and depressions to flood. Water standing in naturally flooded fields appeared to be more harmful to corn plants than water applied artificially in the experiment. Corn yields were reduced in the potholes after 24 hours of flooding. After 4 to 5 days of flooding (96 to 120 hours), corn plants were completely killed in the potholes. On one pothole, corn yields dropped 40 percent when flooded for 3½ days (about 84 hours). Yet after corn plants had been flooded for 96 hours (4 days) on the artificially flooded plots, there was only a small reduction in yield.

On the flooded experimental plots, water was slowly percolating through the soil profile for the entire period of flooding. This could have provided an aeration effect and supplied the plants and soil microorganisms with sufficient oxygen. In the potholes, the water became stagnant and there would be a deficiency of oxygen. Soil aeration measurements on the experimental plots in 1968 showed oxygen was present at the time of flooding.

Soil microorganisms require a certain amount of free oxygen for normal metabolism. These soil microorganisms oxidize vegetative growth to form organic matter and control nitrification, ammonification and other chemical activity in the soil. Under flooding conditions where there is no oxygen, these oxidative processes are slowed down. And the products of anaerobic (without oxygen) oxidation of organic matter are different from those resulting from aerobic (with free oxygen) oxidation. Aerobic oxidative processes could be going on in the artificially flooded plots and helping corn plants to survive.

Carbon Dioxide

Carbon dioxide is produced in both aerobic and anaerobic decomposition of organic matter. Under flooded conditions, the carbon dioxide would be dissolved in the water. On the artificially flooded plots, the water passed through the soil profile continuously and there would be no accumulation of carbon dioxide in the water.

In naturally flooded fields where water is standing for a few days, there is a gradual accumulation of carbon dioxide in the water. In time, it may reach a concentration high enough to be toxic to the plant roots.

Scientists do not agree whether plants are injured under flooded

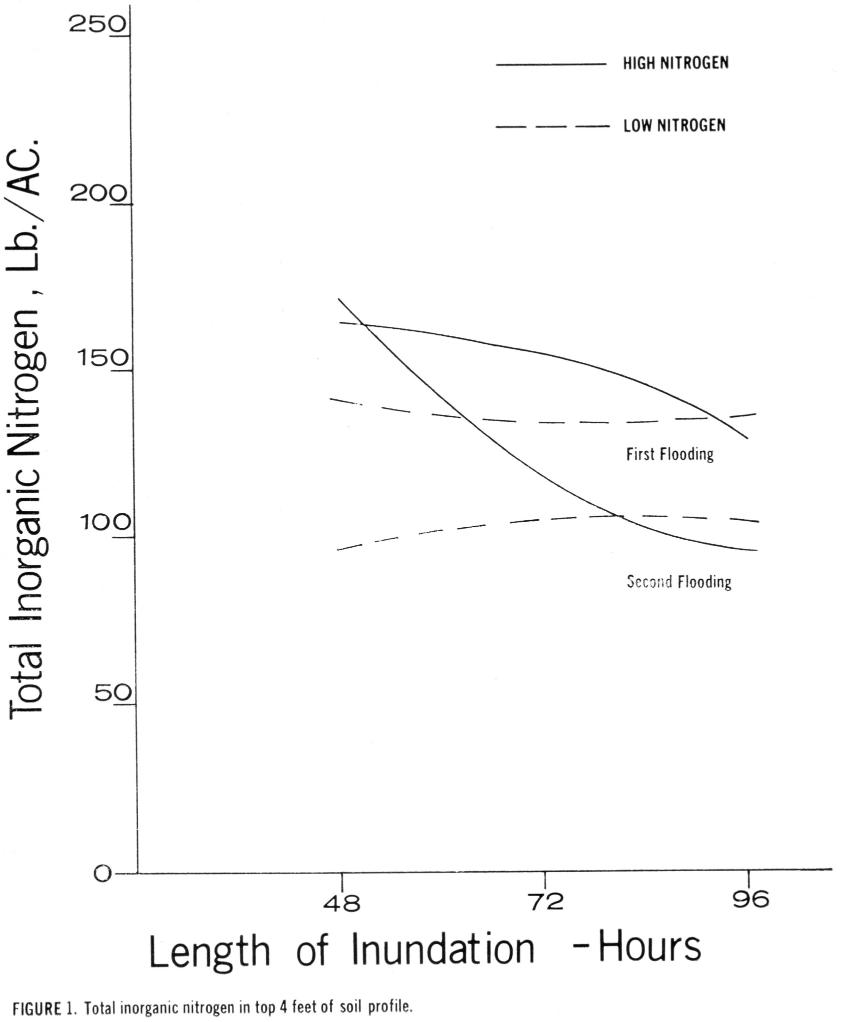

FIGURE 1. Total inorganic nitrogen in top 4 feet of soil profile.

FLOODED POTHOLES such as this one were common in Iowa this year. An Iowa State study to determine the effect of flooding on corn yields shows many factors are involved.

conditions primarily through lack of oxygen or by carbon dioxide toxicity. It is quite likely that plants in naturally flooded potholes were killed by a combination of the two.

But the difference in damage to corn plants standing in potholes and those on the artifically flooded plots indicate that yield reductions and reduced plant growth are not caused by excess water itself.

Depth of Flooding

Some people consider depth of flooding as the most important factor in estimating damage caused by flooding. Results of these studies indicate that shallow flooding at early stages of plant development may produce greater damage than moderate depths of flooding when corn is in the silking stage.

If flooding occurs more than once a year on the same land, the second flood may cause large amounts of damage or very little damage, depending on when the second flood occurs. If a crop were flooded in early spring and again later on in the growing season, probably most of the damage would be caused by the first flood. In evaluating damage with multiple floods, the time of the growing season at which each flood occurs must be considered to make an accurate estimate.

Another varying factor is the soil characteristic. On floodplains where the soil has a permeable subsoil similar to that used in the experimental area, flooding will not cause as great a reduction in crop yields as flooding on a floodplain with an impermeable subsoil. The permeable subsoil does exist, however, on many floodplains.

Summary

The following conclusions can be drawn from this study of flooding:

- **Corn is affected most by flooding at the early stages of growth. Once it has reached the silking stage, shallow depths of flooding will not cause any noticeable amounts of damage.**
- **As the duration of inundation increases, corn yields decline. Under some natural flooding conditions, corn plants in the early stages of growth will be completely killed by inundation periods of 4 to 5 days (96 to 120 hours).**
- **Injury to corn plants may be caused by factors other than excess water. The main factors causing injury to corn plants probably are a deficiency of oxygen and carbon dioxide toxicity under natural flooding conditions.**
- **High nitrogen applications have a greater effect in reducing losses at early stages of growth.**
- **Large amounts of nitrogen may be lost from the soil during flooding. Nitrogen may be lost by leaching or volatilization.**